

AN EFFECT OF VACUUM ANNEALING & TEMPERING PROCESS ON AISI431 GRADE STAINLESS STEEL MATERIAL

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ABSTRACT

Stainless steel is well known for its good corrosion resistance, which are cheaply available in the market. Martensitic stainless steels find rare applications because of their high hardness and wear resistance in tempered condition. In order to decrease their hardness and promote the ductility AISI431 Grade martensitic stainless steel samples were subjected to vacuum annealing and vacuum hardening/tempering. 3 samples were chosen and were subjected to vacuum annealing and named as VA1, VA2, and VA3. 3 samples were subjected to vacuum tempering and named as VT1, VT2, and VT3. All the samples underwent with a pin on the disc testing to analyse the wear behaviour. All the samples are subjected to various metallographic test to get the results like optical microscope results, hardness tests, scanning electron microscope results and (EDAX) Energy Dispersive Spectroscopy. An untreated sample is used for the comparison with the treated samples. The microstructure comprises of tempered martensite with haphazardly dispersed carbides in the framework.

KEYWORDS: AISI 431 Martensitic Stainless Steel, Metallographic Tests, Vacuum Annealing, Vacuum Hardening & Tempering

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INTRODUCTION

Stainless steel's resistance to corrosion and staining, low maintenance, relative inexpensive and familiar lustre make it an ideal base material for a host of commercial applications. Though these stainless steels represent a low percentage of the total amount of steel produced, they have a technological and economic importance because they are the key materials for chemical, petroleum, process and power industries. The effect of these alloying elements differs in some aspects between hardenable and non-hardenable stainless steels. Alloying elements such as molybdenum enhances resistances to pitting corrosion in salt water environment (Peckner and Bernstein 1977). Carbon, titanium, aluminium and copper are added for strength. Nickel, molybdenum and nitrogen are added to modify their structure and enhance the properties such as formability, strength and cryogenic toughness (Sedriks John 1979).

MATERIALS AND METHODS ADOPTED

Table 1: Composition of AISI 431 grade Martensitic Stainless Steel

Composition of AISI 431 Grade Stainless Steel	C	Mn	Si	P	S	Ni	Cr	Fe
Percentage %	0.2	1	1	0.04	0.03	2.50	17	Remaining

Grade 431 stainless steels are general-purpose martensitic stainless steels containing 11.5% chromium, which provide good corrosion resistance properties. However, the corrosion resistance of grade 431 steels can be further enhanced by a series of processes such as hardening, tempering and polishing. Quenching and tempering can harden grade 431 steels. They are generally used for applications involving mild corrosion, heat resistance and high strength. Martensitic stainless steels are fabricated using techniques that require final heat treatment. These grades are less resistant to corrosion when compared to that of austenitic grades. Their operating temperatures are often affected by their loss of strength at high temperatures, due to over-tempering and loss of ductility at sub-zero temperatures. Grade 431 stainless steels are resistant to hot gases, steam, food, mild acids and alkalies, fresh water and dry air. These steels obtain maximum corrosion and heat resistance through hardening. However, grade 431 steels are less corrosion resistant than austenitic grades and grade 430 ferritic alloys containing 17% chromium. Smooth surface finish offers improved performance of steels.

Specimen Specification

The specimens were machined and cut by wire cut electric discharge machine. The specimens were etched and cleaned using sulphuric acid. The specimens were annealed to 2 hrs, 4 hrs and 6 hrs. The specifications are given below.

Load: 2 kg, Speed: 1000 rpm, Track diameter: 10 mm, 20 mm, 30 mm, Operating condition: Dry, 28⁰C room temperature, Diameter of the disc: 150 mm, Height of the disc: 10 mm, Diameter of the pin: 08 mm, Length of the pin: 30mm, Material of disc: Stainless Steel, Material of pin: treated by annealing & vacuum tempering.

Wear Testing with Pin-on-Disc Apparatus

The test method covers a laboratory procedure for determining the wear of materials, during sliding using a pin-on-disk apparatus. Materials are tested in pairs under nominally non-abrasive conditions. The principle areas of experimental attention in using this type of apparatus to measure wear are described. The co-efficient of friction is also determined.

The pin on disc wear test is conducted with two specimens. A pin and a disc. The disc is rotated against sliding pin acting with a constant load. Here untreated with 6 treated samples are to be replaced immediately for wear test. Wear results are reported as volume loss in millimeters for the pin and the disc separately. The amount of wear is determined by measuring appropriate linear dimensions of both specimens before and after the test. Linear measures of wear are used frequently in practice, since loss is too small to measure precisely. If loss of mass is measured, the mass loss value is converted to volume loss using an appropriate value for the specimen density.

RESULTS OF OPTICAL MICROSCOPE ANALYSIS

The specimens were prepared by the standard metallographic practice as per ASTM standards for the microscopy study. The specimens were mechanically polished using emery papers followed by lap polishing with diamond paste.

The etching process was carried out in oxalic acid solution at room temperature for 15 seconds. Oxalic acid is preferred that it will reveal clearly the compound zone on the immediate surface and stable nitrides in the case directly. After etching, the specimens were rinsed with water immediately and vapour degreased to ensure the clear reveal of microstructure. The microstructure of the heat treated specimens was photographed using the clemex image analyzer.

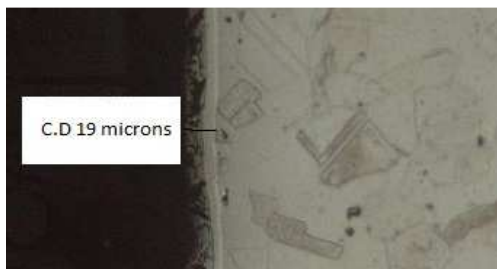


Figure 1: Microstructure of Untreated Specimen



Figure 2: Microstructure of VA-1 at 900°C – 2 Hrs



Figure 3: Microstructure of VA- 2 at 800°C – 4 Hrs

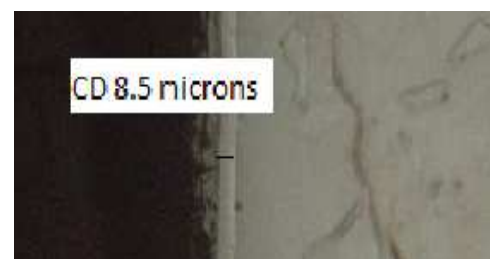


Figure 4: Microstructure of VA-3 at 700°C – 6 Hrs

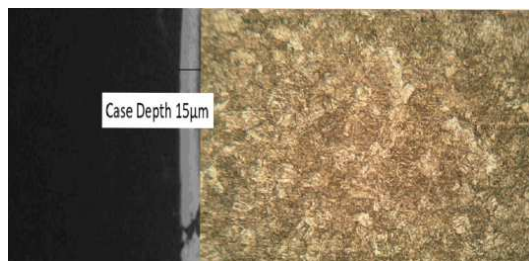


Figure 5: Microstructure of VT-1 at at 550°C-2Hrs

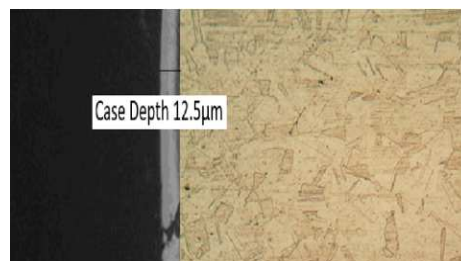


Figure 6: Microstructure of VT-2at 640°C-2Hrs

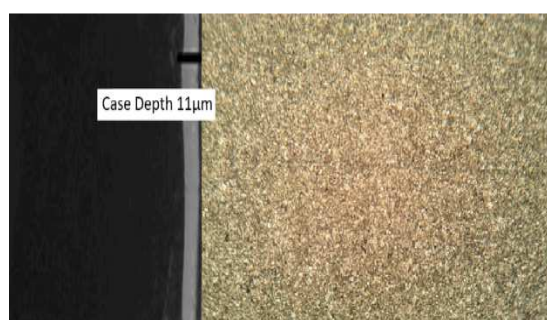


Figure 7: Microstructure of VT- 3at 760°C-2 Hrs

From the above diagram, It has been noted that a case depth of 19 microns was found in untreated specimen and in vacuum annealing specimen it was found to be 16, 12, 8.5 microns. The objective is to promote ductility and maintain medium hardness in AISI 431 Grade stainless steel. Similarly the case depth was found to be 15, 12.5 and 11 microns in vacuum tempering specimens. A re-heat treatment were performed in AISI 431 Grade stainless steel called Tempering, in

order to promote ductility and maintain medium hardness of the material.

SCANNING ELECTRON MICROSCOPE IMAGES

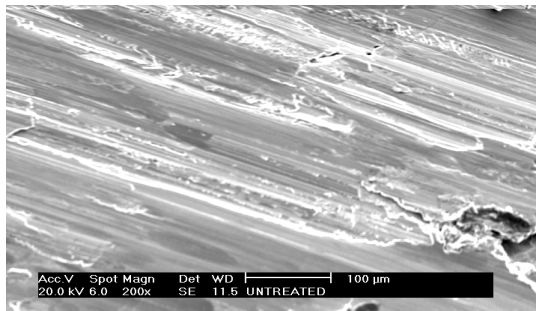


Figure 8: SEM Image of Untreated Specimen

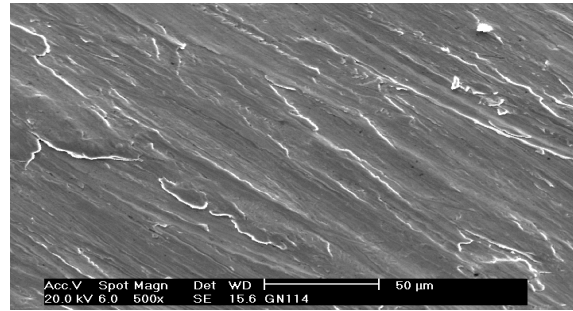


Figure 9: SEM Image of VA 1

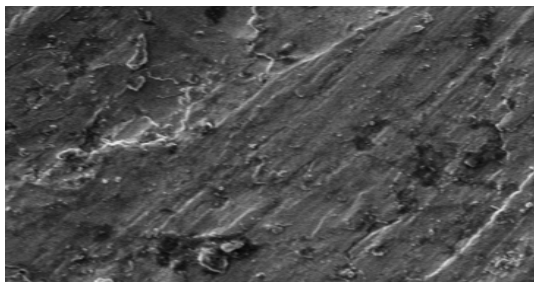


Figure 10: SEM Image of VA 2

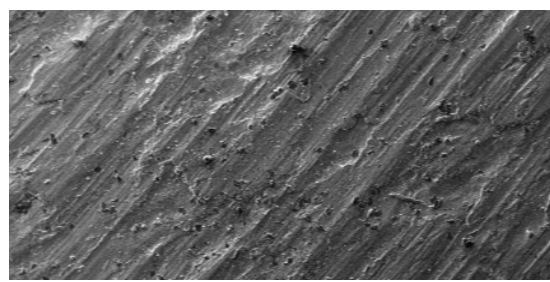


Figure 11: SEM Image of VA 3

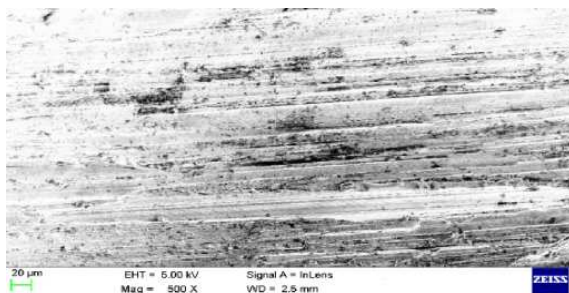


Figure 12: SEM Image of VT 1

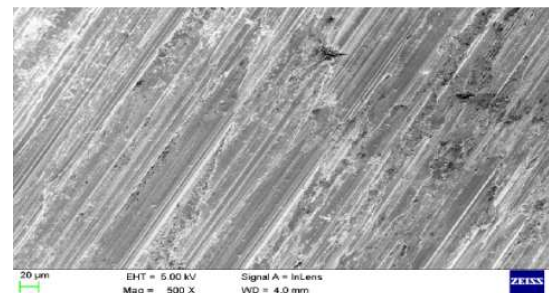


Figure 13: SEM Image of VT 2



Figure 14: SEM Image of VT 3

From this research work, it was focused on the investigation of the effects of full annealing and vacuum tempering process on 431 Grade stainless steel material. The objective is to have a comparative study on the above two process and to determine the best process, which improves wear resistance in order to improve the life of material in power plants, food processing industries etc. Many research scholars investigated on a surface and wear behaviour of 431 Grade stainless

steels, but few results were available. From the scanning electron microscope results, it was found that the more peel of material from untreated specimen. At the time of annealing and tempering treatment increases, wear decreases and wear loss decrease on the stainless steel material. There found to be less wear of material when it is subjected to load. Thereby wear resistance of the material increases, improving the property of ductility in stainless steel material and thereby decreasing the hardness.

The pin on disc wear tests were carried out at a constant load 2 kg and a sliding distance 10 mm, 20 mm and 30 mm with constant speed of 1000 rpm. The wear loss was found to be 0.0066 grams in untreated specimen. The wear loss was found to be 0.0039, 0.0027, 0.005 grams for vacuum annealing specimens. As the time of treatment increases, wear loss increases. The wear loss was found to be 0.0028, 0.0020, 0.001grams for vacuum tempering specimens.

CONCLUSIONS

The effect of Vacuum annealing and vacuum tempering treatment process on the wear behaviour of martensitic stainless steel AISI 431 were studied, by using a pin on disc apparatus, and finally it was analysed by various metallographic tests. The important conclusions drawn from this work are:

- Within the range of test variables used for wear test, mild oxidative mode of wear was measured. The main reason for the reduction in the wear rate was due to the strengthening of martensite matrix by fine precipitates of carbides.
- In annealing process, the martensite fine grain structures were converted into coarse grain structures. Thereby ductility and softness were promoted on the material.
- In tempering process, due to the reheat treatment of stainless steel material, hardness and ductility were equally stabilized.
- From this work, Untreated sample has given more wear, as the stainless steel material is hard and brittle in nature. The wear behaviour of vacuum tempering specimen is better than a Vacuum annealing specimen.

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